

e-Technologies in Engineering Education Learning Outcomes Providing Future Possibilities

E-Technologies for Improving Engineering Education at a Distance

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Abstract

Improving higher education can be characterized by (1) increasing access, (2) decreasing costs, and (3) improving learning outcomes. However, it is not necessary that attempts to improve higher education affect all three positively. For example, it might be that increasing access to more or different students causes costs to increase; whereas learning outcomes are maintained at some previously acceptable level, but an audience exists that is willing to pay the increased cost. Improving learning outcomes also might increase costs without changing access. But, decisions on when or how to improve higher education must be based on consideration of all three characteristics and not just one alone such as just trying to improve learning outcomes.

This paper summarizes, based on studies and experiences, the value e-technologies play in our attempts to improve higher education by focusing on the use of e-technologies to support distance-learning students for each of the three characteristics enumerated. The paper then concludes with a set of questions whose answers should further aid the understanding of the use of e-technologies in engineering education.



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television, satellite television receiving systems, computers, and telecommunications networks of computers. Each generation of technology has had its advocates and evangelists, each promising the end of education, as we know it. Yet, a visit to any traditional campus classroom shows little impact other than the instructor's use of Microsoft PowerPoint™ slides that most students now refer to as "death by PowerPoint."

Today, the application and use of technology (media) to support higher education has become a hot topic with differences of opinion by nearly everyone involved in the discussion. Some university faculty and administrators argue that the application of technology only adds to the high cost of education. The counterpoint to this view is expressed by those who say that to date technology has only been a "bolt on" to traditional education and obviously the costs will be higher since not only are we doing the old already high cost education but we are adding still higher cost items to it which must make the costs still higher. These individuals state that we must redesign our courses based on what we want to accomplish before we

can do an honest cost analysis. Certainly this is true.

I. Introduction

There has been a raging controversy in the literature ever since Clark [1] published his paper and the "the no significant differences phenomenon" bibliography [2] reinforced Clark's earlier work. Both of these concluded that media (a curious choice of words since the examples compared included videotape, satellite broadcast television delivery, computers, etc., in fact, what we would prefer to have called technologies rather than media) does not improve learning outcomes. Educational technology evangelists have been convinced for the past hundred years that each new technology (media) would revolutionize learning and educational institutions. The movement started with the use of the postal system and so-called correspondence courses back at the turn of the twentieth century. Schools and colleges were founded to use this technology and great things (for example, a democratization of education) were promised. Technologies followed at a steady pace, radio, film, closed circuit

On the other hand, billions and billions of dollars have been spent on computing and networking technology by educational institutions from kindergarten through higher education with little or no impact on learning outcomes. Higher learning institutions have not seen dramatic improvements in entering students who have been exposed or used computing technologies in their formal or even informal education. We, that is, those of us involved in higher education, continue to be told that we have a "new" generation of computing literate students who have spent many hours using this technology but we wonder if this is not the same description we have heard before about their television literacy or videogame literacy. Surely, just because students spend hundreds or even thousands of hours listening to music on their walkmans, discmans, MP3 players, and in their rooms does not make them knowledgeable about music other than they can identify particular musical groups. Long-term exposure alone does not constitute musical literacy; at most it might be considered a form of limited music appreciation.

However, thousands of hours of learning and training to play the violin, piano or another instrument does constitute musical literacy.

Perhaps we should just back off and ask: what is the role of technology in education? Typically, we think of improving education as having three components: increasing access to those who may be denied for whatever reason, lowering costs and increased quality, i.e., improved outcomes. This is not to say that we should continue to do business as usual but just use more technology. No, the entire spectrum of opportunities using technology must be considered. But first, let us examine what we know from the past before proposing some new experiments for the future.

II. Increased Access

Increasing access for individuals unable to attend traditional universities is the area where technology (media) has played a major role in higher education. First the postal system, then radio, television, computers and now the Internet, e.g., the World Wide Web (WWW), have all contributed to greater access for students. The important point is that greater flexibility is added to the educational system by breaking down time and place barriers.

Traditionally there was only one way to view the issue of increased access, that is, to reach new students that could not be reached otherwise. Today, there are at least two other access issues: the availability of information that may be difficult to access without new technologies, and technology may also lead to greater access to communication avenues at the level of both student-to-student, and between faculty and students [3]. In the following sections, the first and traditional access issue will be discussed more fully than the second two access issues because these are of more recent introduction.

A. Student Access

Reaching new students via media, or technology, has a long history in education dating back to the beginning of the twentieth century. In 1965, Colorado State University and a few other U.S. universities began offering engineering master's degrees at a distance. Students were no longer required to attend classes on campus. The technology that enabled this new opportunity to serve un-served working professionals was the low price of a videocassette player/recorder. Classrooms were modified to be television "candid" classrooms. Videotapes of on-campus classes were mailed or delivered by courier to the remote students. Students interacted with their instructors by telephone and/or facsimile. In 1984, the National Technological University extended this model by enabling classes to be broadcast live from its participating universities. By 2002, these two universities alone had awarded nearly 2000 master's degrees to students who never set foot on a traditional college campus as part of the

process of earning their advanced degrees. In survey after survey over these years, more than 80% of the students have responded that if it were not for distance learning opportunities they would not be receiving their master's degrees. As well, in surveys of these students' employers, it was found that many of the students taking advantage of the distance learning programs were considered to be among the "best" of their employees. In other words, the flexibility of breaking the time and place barriers had opened up opportunities for a group of students previously unable to continue their education. One issue to note here, however, is that this use of technology did not include any change in pedagogy. The distance-learning students were participating in the same classes as their on-campus colleagues, typically lectures using textbooks, problem sets, examinations and/or the writing of technical research papers, etc. Interestingly enough, the distance learning students performed comparably, usually slightly better, than their on-campus peers further supporting "the no significant differences phenomenon" results.

B. Information Access

Technology is very useful for providing access to information that may not be shared as widely without technology. For example, the development of the WWW and digital libraries [4] provides students and faculty with information from many previously untapped sources. However, an important question only now being addressed is: does this access to more information lead to better learning by students. Several studies imply that students may become less critical thinkers when information becomes so available that "thinking" does not appear to be necessary [3, 5-7]. Having information available does not necessarily result in good use of the information! Others claim that technology can be used to enhance the development of students' thinking skills [3, 8-11]. Once again, it would appear that the question remains unanswered or perhaps this is just another example of "the no significant difference phenomenon."

C. Communications

Communication via technology has as many benefits as costs [3]. One downside to instant communication was identified as the growing expectation of students that faculty are, or should be, available 24 hours a day, seven days a week through technology, e.g., email.

There are several benefits related to communication via technology. Several investigators found that technology can lead to more student-to-student interaction [12-15]. Having greater communication among students is an important component to the cooperative education movement that has been one of the more popular educational reform movements.

Communications can also be used to do completely new activities such as giving students an international exposure as described in a companion paper [16]. Before computer networks,

joint projects such as these were impossible. Here it will be necessary to judge whether or not these activities are worth increased costs. Surely, in a world bound for more and more globalization efforts, these types of projects may be seen as a necessary part of higher education.

III. Improved Outcomes

Many educators believe that the “no significant differences phenomenon” only compares instructional television with traditional lecture based courses. It is certainly true that most of the articles reviewed fit this category, but other media such as correspondence (reading) courses are covered in the early years of the bibliography, and film, television including interactive television, computers and networked computers are covered during the more recent years. No matter what the media, students do as well using any media, however, when asked, students often expressed a dislike for the media based instruction. We believe that this is simply because media based instruction is different from the educational methods used in the students’ early learning environments such as primary and secondary schools and students are often uncomfortable with non-traditional approaches to learning.

Why is it that the ‘no significant differences phenomenon’ shows that media is irrelevant, and that passive versus interactive learning [2] does not matter? Current thinking is that the model for individual learning is an internal act and that external influences simply become the input for an activity that takes time and reflection in order to be internalized. On the other hand, as Joy and Garcia point out in [17], most of the past studies are flawed because seldom are the controlled learning variables a complete set and many studies are even descriptive rather than experimental. For example, does the instructor’s pedagogical approach impact the learning outcomes? As well, time on task must be the primary first order effect on learning outcomes.

A. Pedagogy

Pedagogy is defined to be the study of teaching/learning methods. Many of these methods are well known: lecturing, the Socratic method, problem based learning (PBL) both coached and self-discovery, collaborative learning, etc. How many methods are there? And, are any dependent on technology? It would appear that all faculty members should understand pedagogy and how it interacts with technology [18] in order to make informed decisions about using e-technologies in engineering education. Faculty development is poor at best in most universities particularly with respect to teaching and learning but changes must be undertaken to remedy this serious shortcoming.

For example, engineering educators have always valued hands-on approaches to engineering education. This is one of the reasons for the dependency of undergraduate engineering

curricula on many sections of laboratory courses. Recently, technology has been seen as a way to either accommodate more students with limited and or out of date laboratory facilities or to provide laboratory experience at a distance [19-26]. It is often taken for granted that this is the way of the future but experiments must be conducted to see if this is really true. In personal discussions with practicing engineers, many have told us that laboratories contributed little if anything to their undergraduate engineering education because the experiments involved technologies that either changed rapidly or became obsolete.

In another case in a very recent study, the opposite effect of technology with regards to gender was identified [14]. In a freshman course in physics for engineering students, female students appeared to benefit from the introduction of technology more than did the male students. It is obvious that the interaction with, and reaction to, technology is a social issue. The gender issues identified here represent some of the issues that need to be carefully investigated. At a time when there is a need for greater diversity in the engineering student population, it is very important to better understand the possible gender biases in educational technology.

Another concern that we have with the use of e-technologies in the classroom is that it becomes very easy for an instructor to just slip into the process of teaching tools. Unfortunately, this is reinforced by industries that are making more and more demands on engineering curricula to produce young engineers who can produce immediately on the job. Engineering educators must never lose sight of the basic goals in engineering education: to produce problem solvers with analytical knowledge, synthesizers with design knowledge, and socializers to work in teams of cross-disciplinary members.

Educators are often criticized for their use of lectures but we believe that few, if any, engineering educators would argue that their students learn from memorizing their lecture notes. Engineering is simply not a subject that can be memorized. Engineering educators believe that the learning that occurs during their courses comes from a continued use of problem solving where the learning process is more similar to compilation rather than memorization. Engineering students learn their engineering through problem solving, and independent and group projects not by passively attending lectures. But lectures do serve a purpose, that is, they act as the course clock or drum beat for the course timing. Most younger age students are not disciplined enough to pursue courses in their own time. One reason that undergraduate engineering programs may suffer lower retention rates is because it takes students a long time to realize that learning engineering is not the same as learning was in their secondary schools.

Since the National Technological University’s founding in 1984, it has had more than 27,000 individuals enroll in advanced master’s level courses in engineering, computer science and

technical management. Consistently over this period the NTU students have slightly outperformed (in terms of grades given by the faculty) their on-campus peers enrolled in the same courses. The data set represents well over one hundred thousand course enrollments. Over the years four media (technologies) have been used: videotape, live television satellite broadcasts, CD-ROM and WWW where thousands of courses with tens of thousands of students have been monitored. The slightly better performance of the NTU students is probably due to the fact they are slightly older than their on-campus peers, on average, and they have self-selected themselves rather than being master's students because they were unable to get a good job when they completed their undergraduate program. NTU's data most definitely supports "the no significant difference phenomenon."

A. Time on Task

Education assessors do not like the metric of seat time as measured by how many hours the student spends in class, yet this measurement lives on because of its ease of measurement in terms of the concept of the credit hour. A few universities have tried to institute and give credit not by the number of hours spent in class but by the number of hours that a typical student should spend on the course material each week, that is, the sum of the number of hours spent in the classroom plus the number of hours spent studying the course outside of classroom time. It would certainly seem that time on task is the primary first order effect in learning. However, few studies include time on task as a primary measurement. Is technology's role here simply the motivator that causes students to spend more time on task? If we had a set of metrics that were agreed to, then we could talk about efficiency in a much stronger way than we do now. Efficiency can always be brought back to a cost, but because true costs are so difficult to consider, trying to specify efficiency this way is a bit simplistic.

IV. Decreased Costs

We argue that the question of cost is probably an impossible question when truly considered from the entire system's view. Sheffield Hallam University in the U.K. is trying to address this question [27] as well as the Mellon Foundation [28]. Professor Paul Bacsich [27] is convinced that it is important to include more than just the institution's costs, i.e., student, individual faculty, university, society, etc. For example, the cost of student failure is never considered in any analysis. It is simply too hard to do. Rather, the typical cost analysis is in terms of the cost of faculty and graduate teaching assistant time. In a recent study at Michigan State University [14], Asynchronous Learning Network (ALN) technology was used to change the offering of a physics-for-engineers course. The authors reached the conclusion that costs savings occurred based on the need for fewer instructors required to teach the course, e.g., recitation sections were removed. There was an increase in some costs for the

added preparation time required for course development using technology—a common finding for these types of projects. This study, as with many of similar nature, does not address the issue of student costs in terms of time, and or materials.

In many cases, costs are simply transferred, for example, having course syllabi and notes on the Web for students to print themselves saves the institution money but significantly increases the costs for the students since the cost of printing for them is much higher than the volume printing within the university. Again, Web access is fine for students at a distance when mailing costs are also included but this is simply not the case for on-campus students.

Any cost analysis must try to include as much as possible, not simply the university's costs. But, because true cost analysis is so difficult, we introduce a fourth category for improving education, namely effectiveness. Because universities do cost analysis based only on their costs, the students get left out of the cost equation. Therefore, we define effectiveness as a way to discuss and include what is good for the student. For example, students driving around parking lots looking for places to park their automobiles is not an effective use of their time.

The most prevalent reason for working technical professionals to pursue a master's degree through NTU is the flexibility offered through the perceived effectiveness of not having to take lots of extra time out of their workday to drive, park and walk to attend a class on a traditional campus. We have spoken with many students who simply state "I have only ten (or some number of) hours each week that I can devote to taking a class," and this number is not large enough to include the times required for non-academic activities like driving. We believe that this is one of the main reasons that NTU appealed to a group of working engineers that had not previously taken advantage of locally provided advanced educational opportunities.

It is certainly true in the United States today that most undergraduate students do not have learning as their primary activity anymore. Four decades ago university students had learning, recreation, culture and dating as the items to fill their 80 or so hours each week. Consequently, students could complete 18, 19 or even more semester credit hours each term. This was required because most undergraduate engineering degree programs required a minimum of 144 semester credit hours for graduation and some required as many as 152. Today, most university students no longer live on-campus. Instead, they live off-campus and own cars, rent apartments, cook and clean for themselves, shop for themselves, etc., all activities that demand their time and attention and take away from time for learning. Also, because they live off-campus, few belong to active study groups that have been shown to be very effective in the learning process. These students' living costs are also higher; therefore many work nearly full-time while attending university. Today's students have already built into their schedules that in taking

the twelve or so credit hours each term that they can handle they will not graduate in the traditional four-year time period. The reaction by state legislators is to demand that degree requirements be reduced to 120 to 124 semester credit hours. So, nearly a full master's degree in course content has been eliminated from undergraduate engineering degree programs and for all the wrong reasons. It is interesting to note that universities include significant human support mechanisms such as housing offices, legal offices, student affairs offices, etc., but have failed to make connections to the academic curricula. Living is just far more complicated today than it was four or more decades ago and it is getting more complicated with every passing year. As educators, we must take these changes into consideration.

V. Future Directions

We believe that it is important for faculty to understand that much of what they think and believe about e-technologies improving learning outcomes is just not supported by studies. However, having reinforced this conclusion, we do believe that there really are some important questions to address concerning e-technologies in engineering education. These questions can be a basis for research and development of e-technology based educational initiatives.

- (1) *Can we design courses that use e-technologies to support the educational processes of the course while lowering course costs?* As we identified above, one criterion for successful implementation of e-technologies is a reduced cost for achieving the same objectives.
- (2) *If such courses can be designed, what do they look like?* It is unlikely that reduced costs will come about using e-technologies as add-ons to existing approaches. A better scenario is to change the way courses are taught.
- (3) *What learning methods are used successfully? PBL? Student-led inquiry? Etc.?* Again, it is unlikely that e-technologies will be effective as add-ons to existing pedagogues. It is important to develop an understanding of how the technology and the pedagogy must mutually adapt for optimal results.
- (4) *Do e-technologies only motivate so that students simply spend more time on task learning?* One prime factor in student achievement is the time spent on learning activities. If time on task is critical, then the ability of e-technologies to both motivate towards, and distract students from time on task, must be better understood.
- (5) *How do student-learning styles affect these questions?* Finally, as with all educational parameters, the individual learner plays a role in the relative success of the learning activity. Research on how different learning styles operate with e-technologies is an important issue to be investigated.

VI. Summary and Conclusions

E-technologies can definitely break the time and place barriers of traditional on-campus education, which may be the only truly documented benefit of using technology. Can this increased access to education be offered cheaper? We think the answer is yes, but traditional universities will probably not undercut in price the cost of traditional on-campus programs and there is a small amount of evidence that at current levels in scale (usually small for engineering courses), the use of e-technologies for increasing access may cost more than traditional on-campus education. Again, these results are based on the add-on of handling distance-learning students as well as the traditional on-campus students rather than the construction of a system to handle just the distance-learning students. These results were certainly the case for the National Technological University and Colorado State University.

With regard to improving learning quality, that is, learning outcomes, current evidence does not support the use of e-technologies to improve learning outcomes. In Richard Clark's foreword to [2], he states even stronger than in his original research papers that "no matter who or what is being taught, more than one medium will produce adequate learning results and we must choose the less expensive media or waste limited educational resources." The conclusion here is that we may choose to use e-technologies in our classrooms but not for the reason of improving learning outcomes. Although others may claim improved outcomes, most studies have been flawed—better fundamental research is still needed. Therefore, the most promising avenue to pursue now is an economic one. Again, as Clark [2] summarizes: "There are benefits to be gained from different media. The benefits are economic. If media researchers and practitioners would only switch their concerns to the economics of instruction, we would discover all manner of important cost contributions from media."

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Gearold R. Johnson is the Emeritus George T. Abell Endowed Chair in Engineering at Colorado State University. He was the Academic Vice President of the National Technological University, one of the world's first virtual universities, from 1994 until 2002. Prior to NTU, Dr. Johnson was a member of the Mechanical Engineering faculty at Colorado State University from 1971 until his retirement in 1994. During many of these years, Dr. Johnson also held a joint faculty appointment in the Computer Science Department. Dr. Johnson received degrees from Purdue University: a B.S. in Aeronautical Engineering, a M.S. in Engineering and a Ph.D. in Mechanical Engineering. He was a NATO Post-doctoral Fellow at the von Karman Institute for Fluid Dynamics in Rhode-Saint Genese, Belgium from 1970 to 1971. He has had Sabbatical leaves at the University of Kent, Canterbury, England; Shape Data Limited in Cambridge, England; and the NTU Foundation in Paris, France. Dr. Johnson's research interests are primarily centered on understanding how technology can be used to enhance student and faculty learning.